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The Analysis of Wiremark

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THE ANALYSIS OF WIREMARK

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ABSTRACT

Wire Mark is the impression left on the paper web by its initial forming fabric. Wire Mark can be explained as differing levels of density in a sheet. By definition, the ideal formation is a sheet which has completely uniform density. Many changes have occured in forming fabrics over the years to resolve this problem. The development of double and triple layer wires for a smoother surface have come about. This thesis takes these forming wires and further modifies the surfaces to reduce wire mark patterns. The action is analyzed by several common paper tests, along with the aid of the M/K formation tester and the densitometer. The results from the M/K formation test show that there is a good possiblity that the modification does some reduction and that this is an area which deserves more attention.

ACKNOWLEDGEMENTS

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Chris Lazaroff of Mead Central Research

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My Mother and Father:
Sharon Carr
Howard M. Birks

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INTRODUCTION

As the printing requirements of our high-tech, high speed industries grow more complex, a greater emphasis is being put on paper formation. The paper s strength and appearance become vitual areas for improvement. Wire Mark, the impression left on the paper web by its initial forming fabric, is a problem many times overlooked. Several ways of dealing with wire mark have developed over the years. A simple method of reduction occurs from calendaring the final web to promote smoothness and uniform density. A more complicated approach is adjusting the jet to wire velocity difference. When the wire speed is less than stock velocity it is said to be "rushing" the wire. When the wire speed is higher than the stock velocity it is said to be "dragging". It has been stated that the rush side produces a more pronounced wire mark. Adjusting the jet to wire ratio can be very time consuming. A reduction method that attempts to deal with the problem before the papermaking process is that of modification to the forming fabrics surface. In short, this involves sanding down the knuckles of the fabric to bring about a smoother surface.(1)

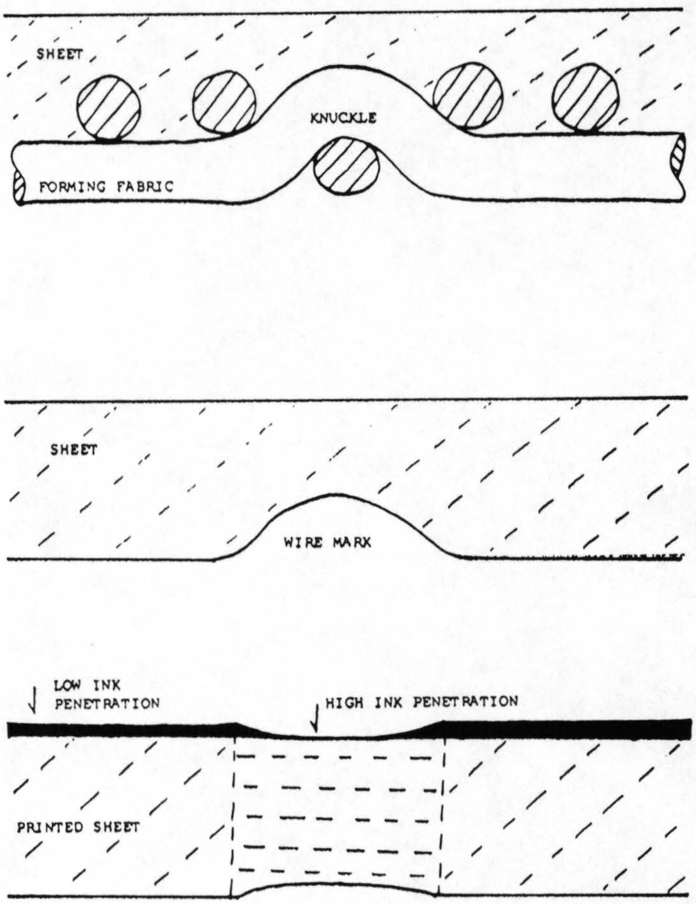
OBJECTIVE

Although sanding of the forming wires has been done on an industrial scale, it has never been documented that it actually reduces wire mark. It is the objective of this thesis to simulate the sanding of forming fabrics and gather data to determine if the method is a form of wire mark reduction.(2)

BACKGROUND INFORMATION

The ideal formation is a sheet which has completely uniform density. Wire Mark is used to explain the levels of density difference caused by the structure of the forming media. This density difference occurs when a sheet is being formed on a forming fabric, it will have thick areas formed over the holes and thin areas over the knuckles. During pressing the thick areas are compressed more than the thin areas which results in a sheet having differences in density.(3) Figure 1. shows an illustration on the formation of wire mark. The areas over the knuckles will have low density, low gloss, be rougher and have high porosity. When printed, these areas will have greater ink

FIGURE 1.
EFFECT OF WIREMARK ON PRINT QUALITY



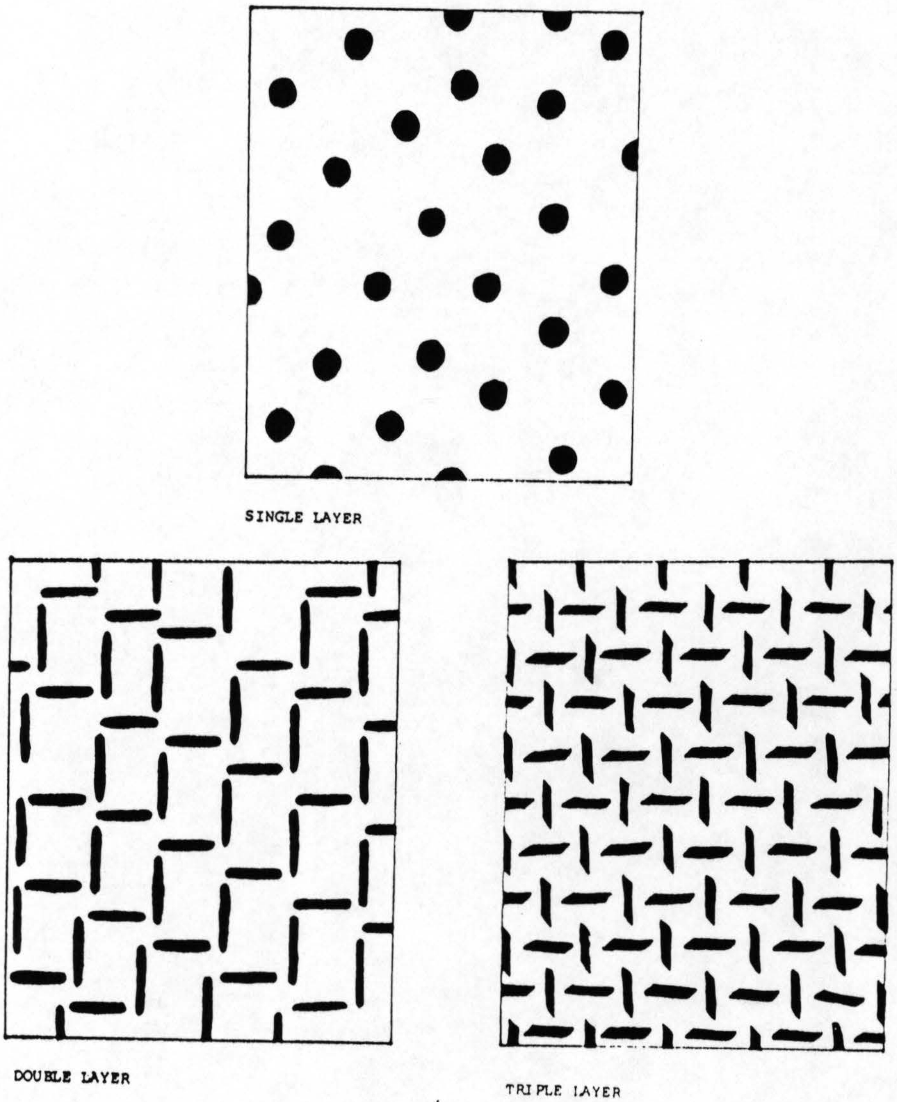
penetration therefore causing a varying image.

Wire Mark can be more or less apparent depending on the wire pattern used in forming. Some different patterns left by varying wire weaves are shown in Figure 2. The application of a fabric design to a paper machine must take into account the grade, furnish, table layout and machine operation. The furnish and grade govern the selection of design and table layout and machine operation govern the actual

drainage characteristics required within the design parameters of mesh and yarn diameters.(4,5)

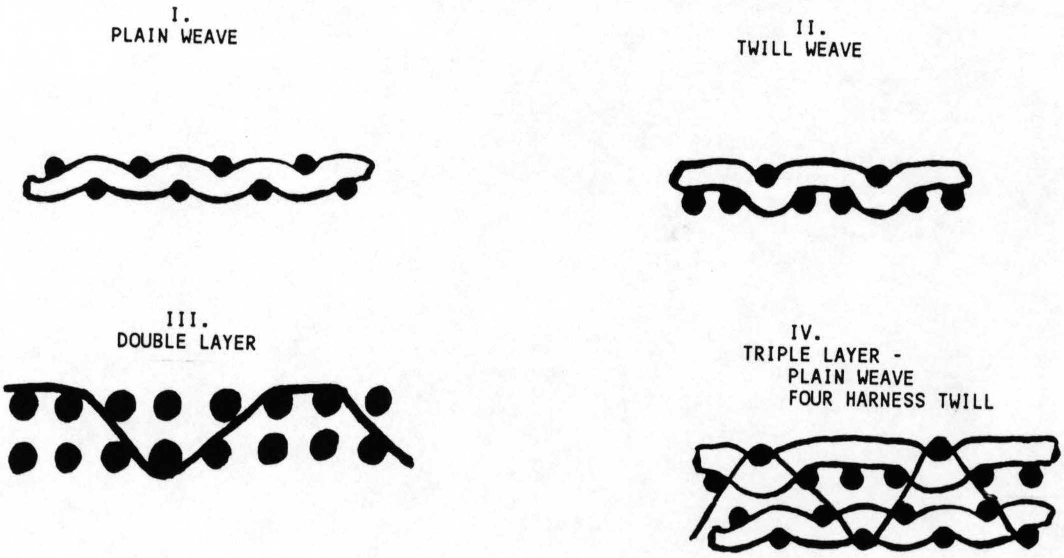
Forming fabric samples for this thesis were donated by Lindsay Wire Co. Four separate wire structures with differing weave patterns were selected for analysis. These four patterns can be viewed in Figure 3.

FIGURE 2.
TYPICAL WIREMARK PATTERNS



The first wire is that of a plain weave. Its construction does not really apply to most Fourdrinier paper grades. Its major application is in coarser sheets such as lap pulp, wallboard, ceiling tile, and insulation board. It also functions as support fabric. The next wire is a semi-twill weave. This weave is the traditional or most commonly used metal wire weave. It's commonly used on low speed, low load machines or tissue machines. Double layer wires are widely used for a variety of grades, and gaining increasing acceptance are triple layer wires. Both fabrics are characterized by an extremely high order of stability. Some of their advantages have proven to be; resistance to damage,

FIGURE 3.
FORMING FABRIC STRUCTURE



improved first pass retention, improved formation, reduced power consumption, reduced offset linting, and less two-sidedness. Newsprint was the first grade to feel a major impact from multi-layer wires and are successfully running today.(6,7,8)

In order to fully understand the forming wires used in paper production, a trip was arranged by High Point Chemical of High Point, North Carolina to observe the weaving process. High Point is a Chemical company that supplies the texile industry. Once in North Carolina the first site visited was Texfi, a texile mill. Here the actual weaving of fabric on looms was viewed. This tour proved to be a good intoduction to the next plant, Huyck Corp. Huyck Corp. produces the clothing for paper machines. Forming wires are formed on large looms exceeding the texile looms by four or five times. The looms are fed machine direction yarns from above and a carrier is shot back and forth carrying the cross machine direction yarns. Huyck is equipped with the largest endless weaving loom in the world. The endless looms weave a continuous belt of fabric which are finished by hand, a process which takes sometimes up to two days to complete. Huyck has the capability to sand forming wires on a large scale,

however, this is only done on a special request from the customer. It remains a special request due to the lack of information to support its advantages.(2)

EXPERIMENTAL APPROACH

The wire mark problem is most apparent in cheaper grades of paper such as newsprint where on machine changes can mean money. Because the pattern left by the forming fabric is so apparent in newsprint it was chosen as the furnish for this thesis. Newsprint is commonly formed on double or triple layer wires, however, not all weave patterns used are incorporated in the newsprint industry, it was in the interest of this thesis to see a broad range of forming fabrics.(9)

A sanding devise was constructed by North American Tool & Engineering. It was comprised of a flat metal plate for the wires to ahere and a sander whose face is slightly larger than the wires. The wires were fixed to the metal surface with water soluble glue. In order to achieve a uniform surface the wires were sanded then rotated 45°, sanded again and so on. Caliper was continually checked to maintain uniformity. Caliper data appears in Appendices IA and IB.

Handsheets were made on the Noble and Wood Handsheet Former, the

first set using a 100% Groundwood furnish and the second set using a 75% Groundwood, 25% Kraft furnish. Both furnishes were obtained from our Pilot Plant facilities. Comparison between handsheets formed on sanded and unsanded wires were made by data gathered from several paper tests. The basic tests included opacity, porosity and tensile strength.
The data collected from these tests are listed in Appendices IIA,B,C,D through IVA,B,C,D.

The forth analysis made was done using a densitometer, obtained from Westerns Printing Department. The densitometer was chosen to help analyze the wire mark by light transmission. The densitometers main function is to distinguish between differing densities of ink. The instrument focuses a light on the surface being analyzed then measures the amount of light being reflected. Its reference is black ink on white paper. A number around 1.5 identifies a solid black suface or complete light absorbtion. This instrument was used to analyze wire mark by placing a standard behind each handsheet which registered 1.5, complete aborbtion. Then the severity of the wire mark becomes a function of the amount of light passing through the sheet and being absorbed by the standard. The densitometer data is located in Appendices VA,B,C,D.(10,11)

The final testing done on the handsheets was preform by Chris Lazaroff of Mead Central Research. It was M/K formation. The M/K formation tester is used to measure the relative amount of basis weight variations in a sheet. The tester determines the number and area of flocs that are present. A floc can be defined as the area of a sheet whose mass per unit area is higher than the mean basis weight of the sheet. The handsheets were clamped to a Pyrex drum. The drum rotates while a photocell mounted on the outside with a light source collects up to 100,000 data points. These data points are stored in up to 64 classes. A Histogram is produced to represent the optical density data points. The peak height of the histogram is the number of data points in the mean basis weight class. The number of classes with at least 100 data points is a bin. From this the formation index is calculated by the peak height over the number of bins. The larger the peak height, the fewer the number of basis weight classes, therefore a higher formation index meaning better sheet formation. The second area of information generated is the floc area/hole area. A picture is generated that shows the flocs and determines the average percent hole area.(12,13) The generated pictures and % hole area for the sheets formed on the double and triple layer wires are seen in Figure 14. at the end of the

TABLE 1.
100% GROUNDWOOD

UNSANDED WIRES

WIRE #	WT. (lb/ream)	OPACITY	TEN. INDEX (Nm/g)	POROSITY	DENSITOMETER READING
1	11	50.5	26.6	266.88	0.41
2	11	47.3	29.9	257.13	0.39
3	11	46.4	23.1	138.00	0.40
4	11	51.3	27.0	176.13	0.50

SANDED WIRES

WIRE #	AMOUNT REMOVED	OPACITY	TEN. INDEX (Nm/g)	POROSITY	DENSITOMETER READING
1	1 mil	50.8	28.6	260.13	0.40
2	1 mil	47.8	29.3	250.75	0.40
3	1 mil	46.5	24.9	134.63	0.41
4	1 mil	51.3	27.2	173.25	0.50

TABLE 2.
75% GROUNDWOOD, 25% KRAFT

UNSANDED WIRES

WIRE #	WT. (lb/ream)	OPACITY	TEN. INDEX (Nm/g)	POROSITY	DENSITOMETER READING
1	18	61.2	36.4	281.25	1.30
2	18	59.4	27.9	272.13	1.31
3	18	58.7	27.4	220.00	1.28
4	18	60.3	37.9	233.63	1.48

SANDED WIRES

WIRE #	AMOUNT REMOVED	OPACITY	TEN. INDEX (Nm/g)	POROSITY	DENSITOMETER READING
1	1.5 mils	61.2	39.3	273.75	1.29
2	1.5 mils	59.8	27.4	268.25	1.25
3	2.0 mils	58.9	29.9	175.63	1.19
4	4.0 mils	60.8	39.5	179.50	1.10

DISCUSSION OF RESULTS section. The final data for the 100% Groundwood sheets and the 75% Groundwood, 25% Kraft sheets is listed in Tables 1. and 2. along with the sheets initial weight and the amount sanded off each wire. Table 3. contains the formation index for the sanded and unsanded wire handsheets.

DISCUSSION OF RESULTS

After reviewing the data in Table 1. and looking at Figures 4., 6., 8., and 10. it's clear to see that sanding 1 mil from the wire surfaces has no impact on the reduction of wire mark. The next set of handsheets were made with an added 25% Kraft. This aided in the overall strength and appearance as seen when comparing the data in Tables 1.

TABLE 3.
75% GROUNDWOOD, 25% KRAFT, FORMATION INDEX

M/K FORMATION
MEAD CENTRAL RESEARCH - CHILLICOTHE, OH

WIRE #1 (formation index)		WIRE #2 (formation index)		WIRE #3 (formation index)		WIRE #4 (formation index)	
	3.0-U		3.8-U		6.0-U		6.1-U
	3.3-S		4.6-S		6.8-S		7.6-S

U - UNSANDED

S - SANDED

and 2. This time the data did show some improvement in some tests. Figure 5. shows that the amount removed from the wires this time still shows little or no reduction in wiremark. Assuming that a more opaque sheet would be formed on the sanded wire, an increase in opacity was expected, however this was not the case. Figure 7. shows that a slight increase in tensile strength is possible. It may be concluded that the more uniform the sheets density the stronger that sheet will be. It is hard to conclude though, if a 4% improvement shows any adequate reduction. Porosity is the measurement of an amount of air through any sheet or how porous a sheet is. It's clear then that the porosity should decrease as the amount of wire marking decreases. In Figure 9. the sheets formed on the double and triple layer wires show a considerable decrease in porosity while the other two show only a slight decrease. This could be due to the fact that the last two wire samples had more area removed than the first two. Consequently, less was removed from the first two because they were of smaller caliper than the last two. The expected results of the densitometer readings was outlined in the EXPERIMENTAL APPROACH section. However, only the forth set of handsheets show a reduction in light abortion. Although the idea of light

FIGURE 4.

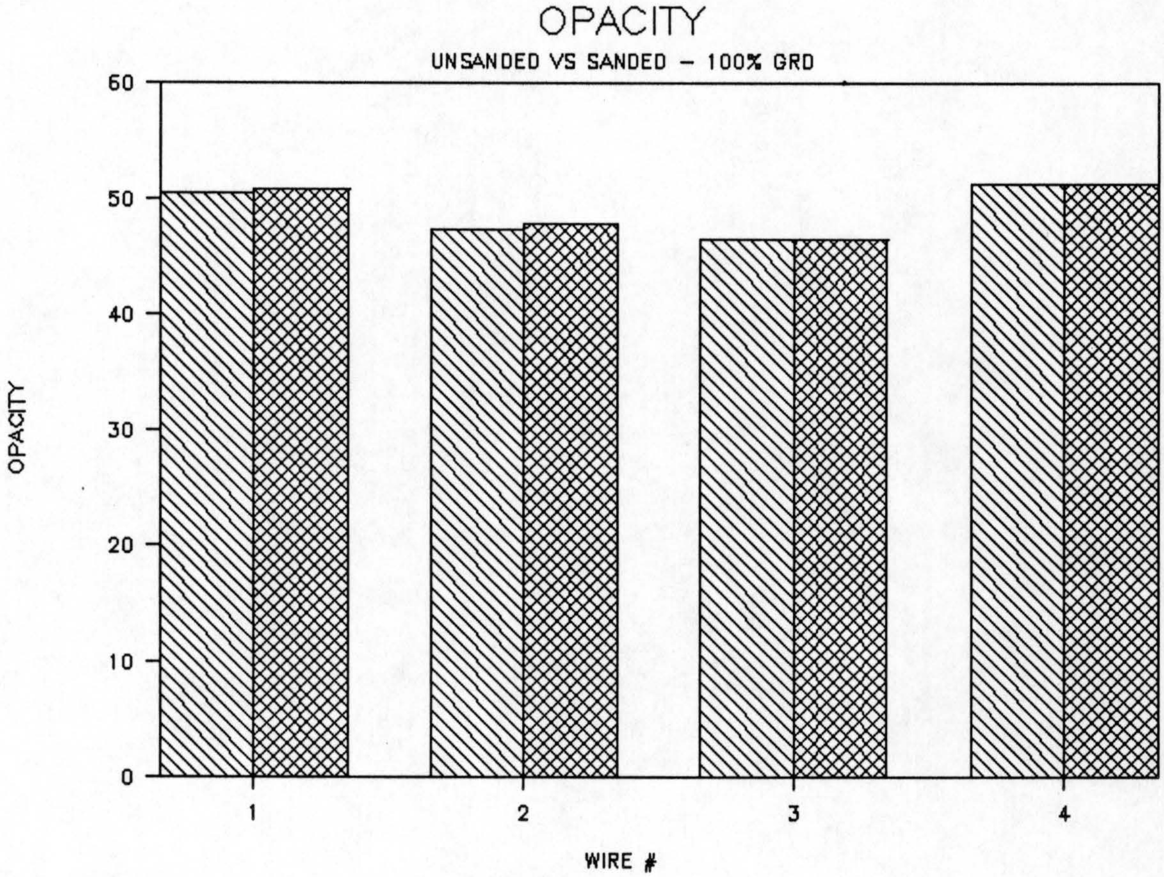


FIGURE 5.

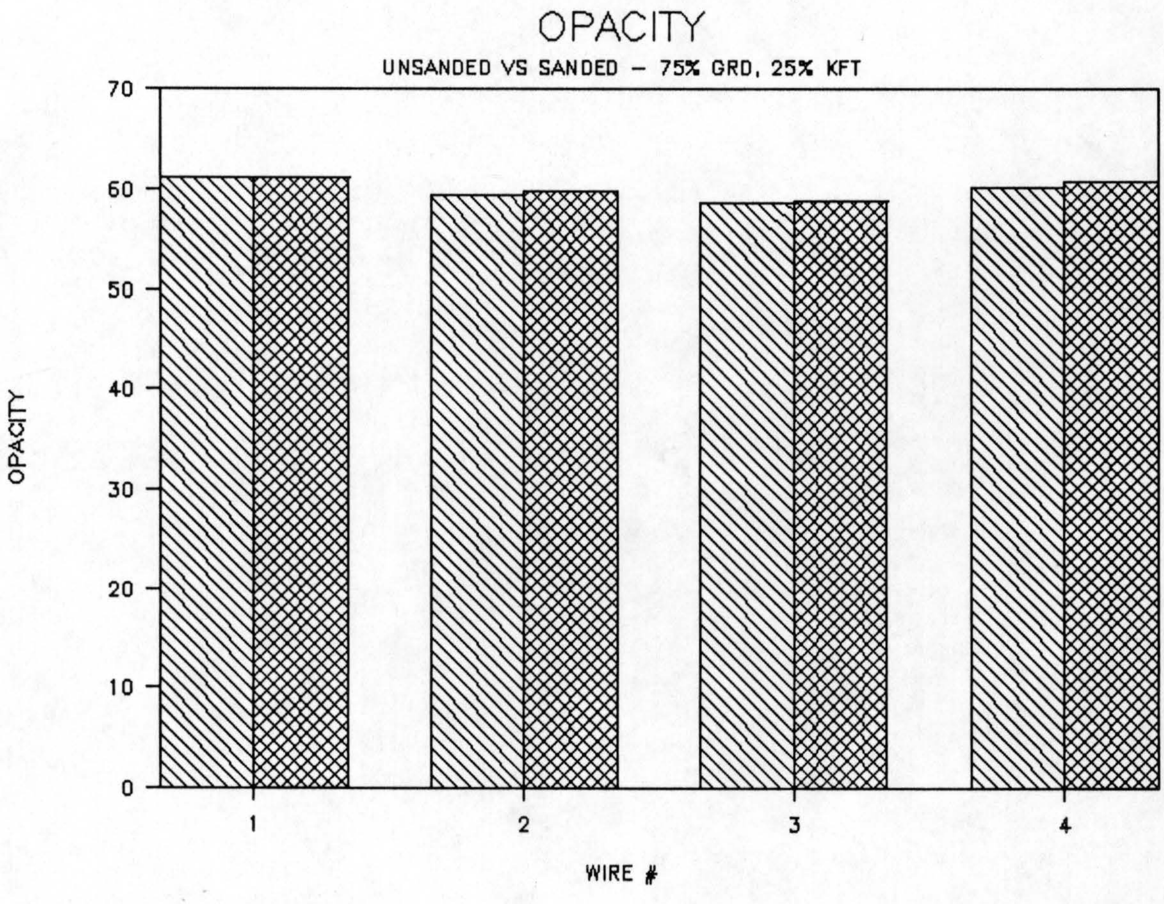


FIGURE 6.

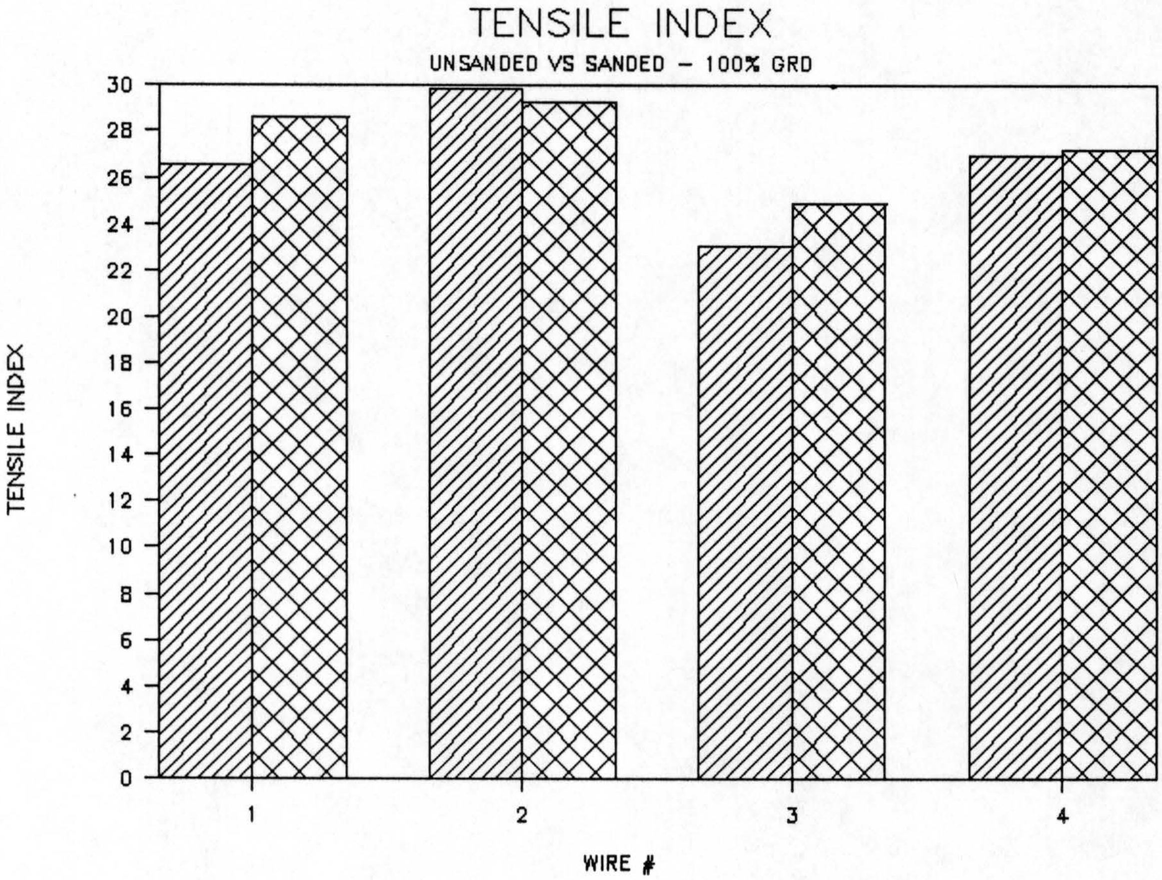


FIGURE 7.

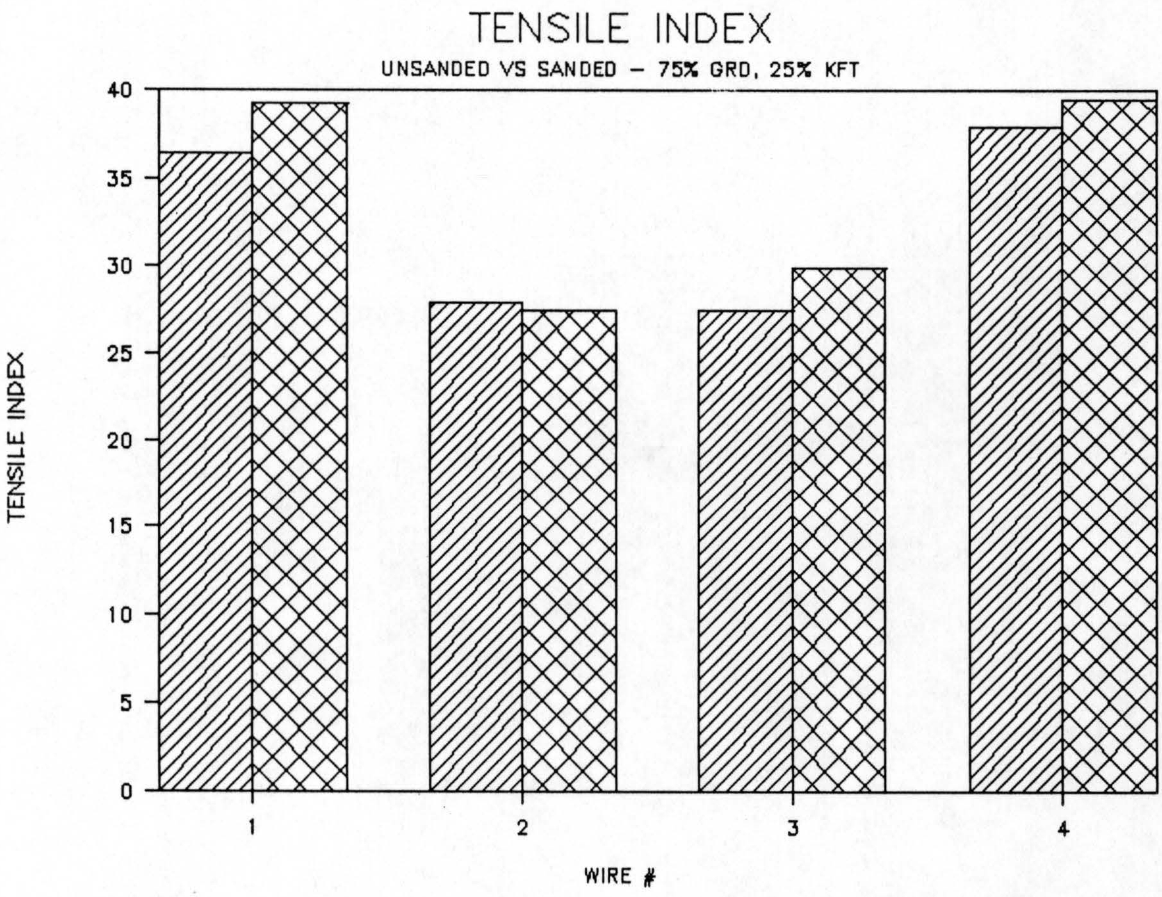


FIGURE 8.

FIGURE 9.

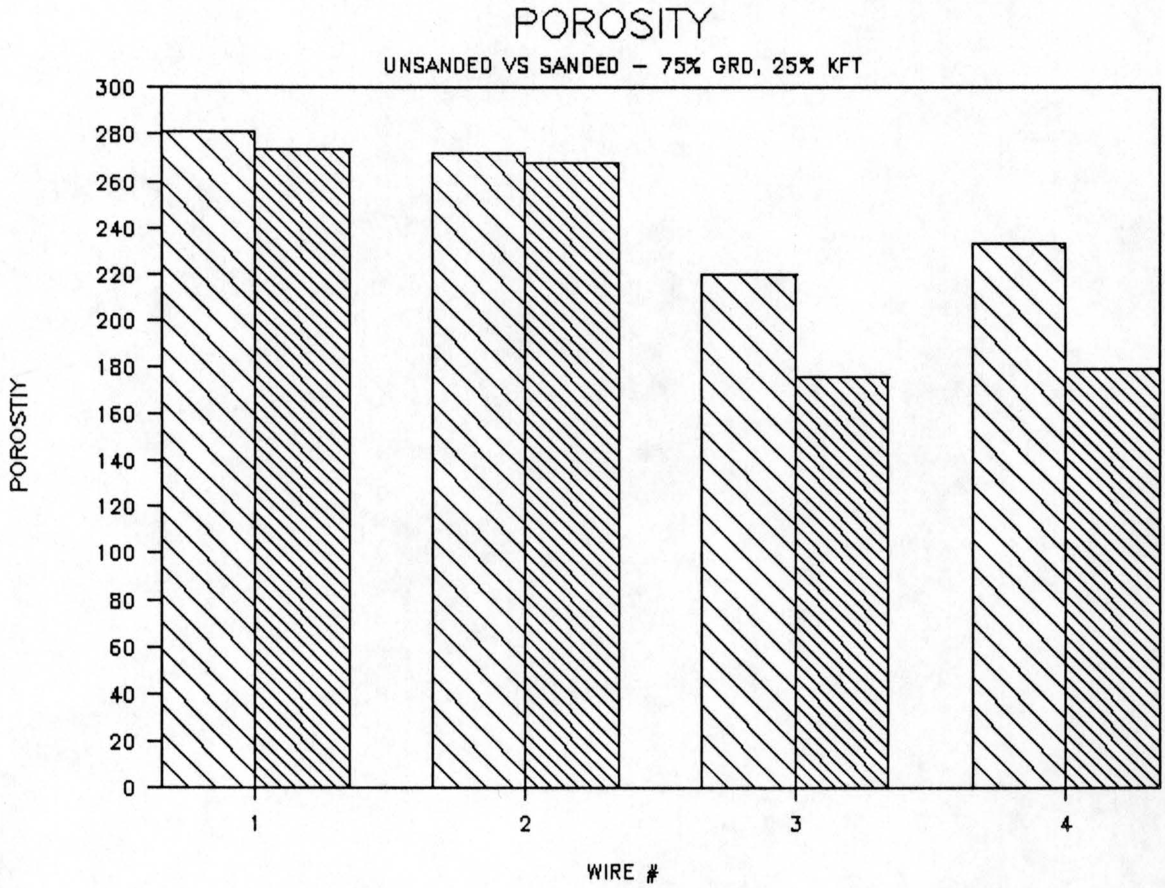


FIGURE 10.

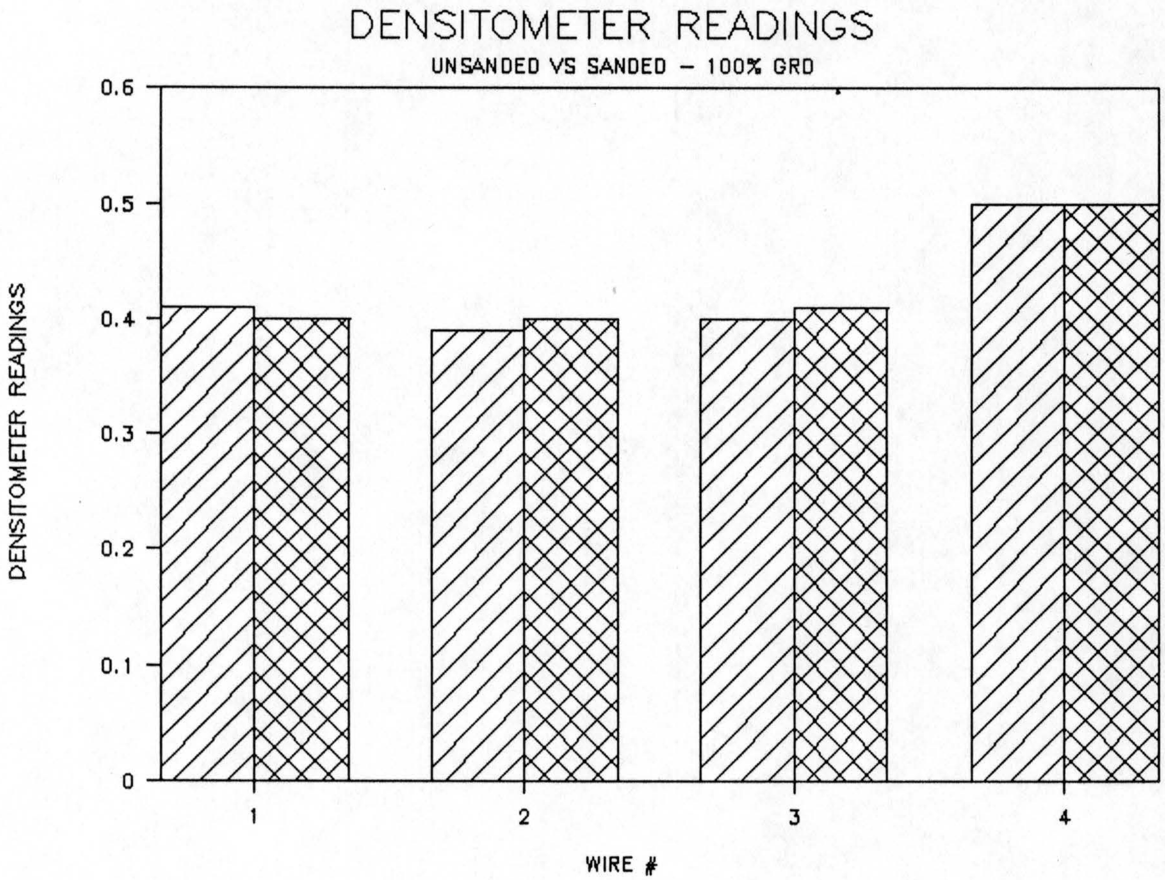
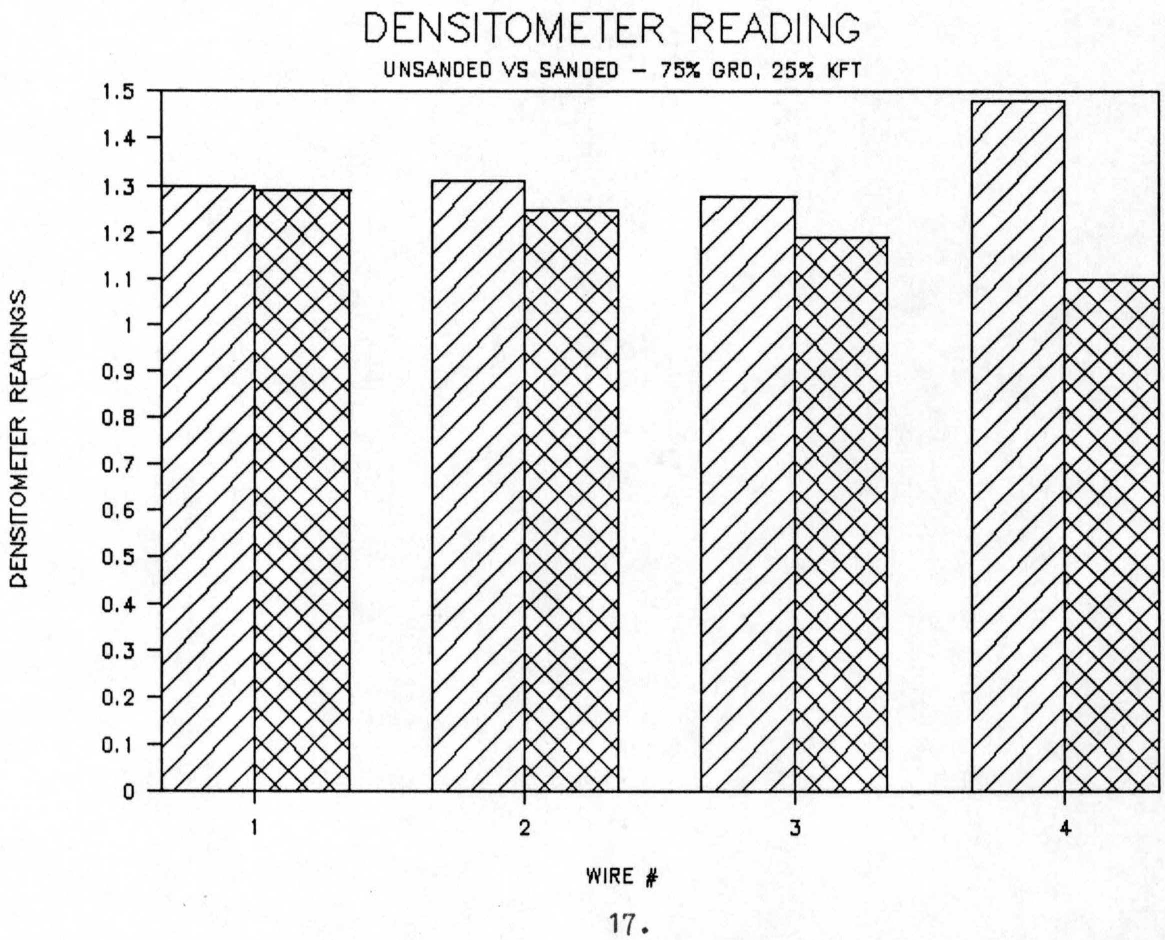


FIGURE 11.



transmission through a sheet is a simple one the fact that it's not a paper tester may render it slightly invalid. Now turning to the formation index, Figure 12., and the floc pictures, Figure 14. Figure 12. shows an increase in formation for every set of handsheets. In Figure 14. both the floc pictures and the percent hole areas indicate an improved formation from unsanded to sanded. The M/K formation tester is a more sophisticated piece of equipment, for this reason it may be more sensitive to small changes in sheet density then the other paper tests. Upon concluding, Figure 13. shows the percent improvement in porosity and densitometer readings for 100% Groundwood compared to

FIGURE 12.

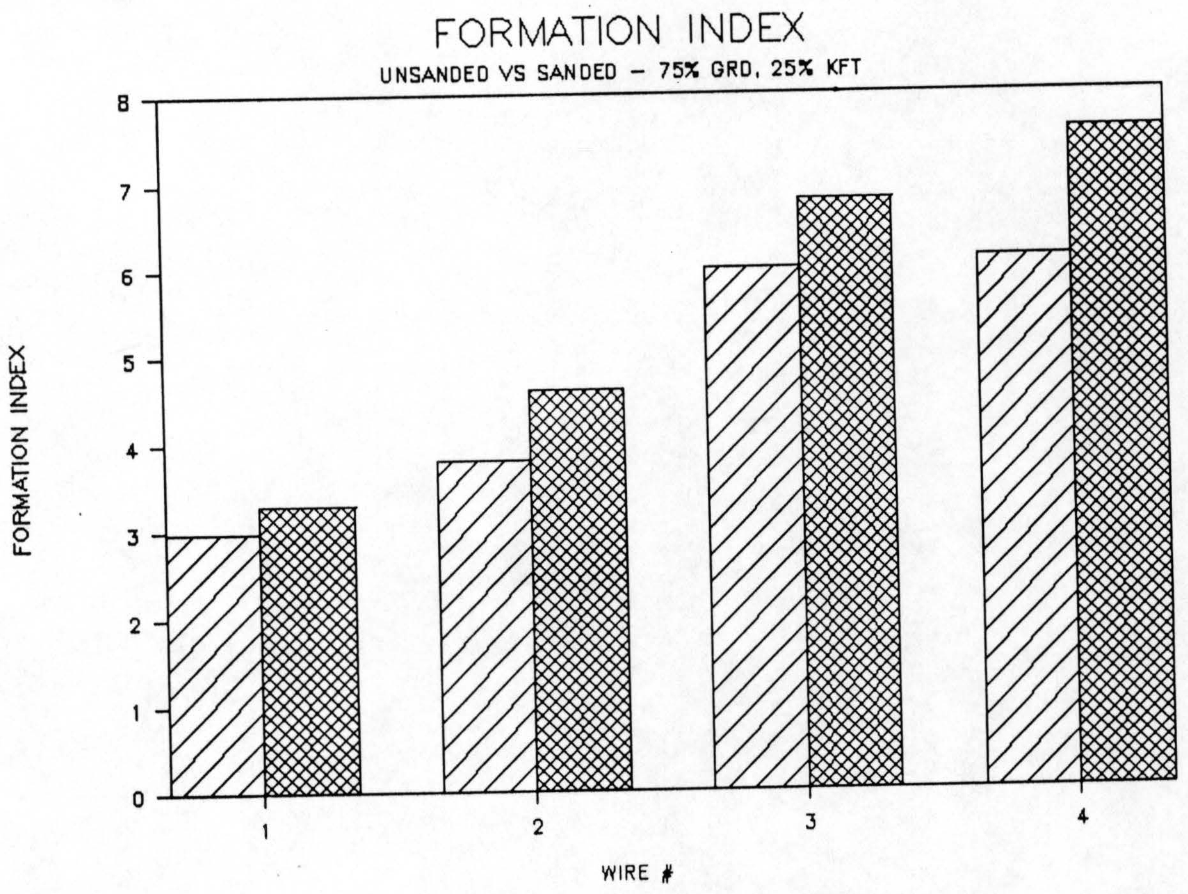
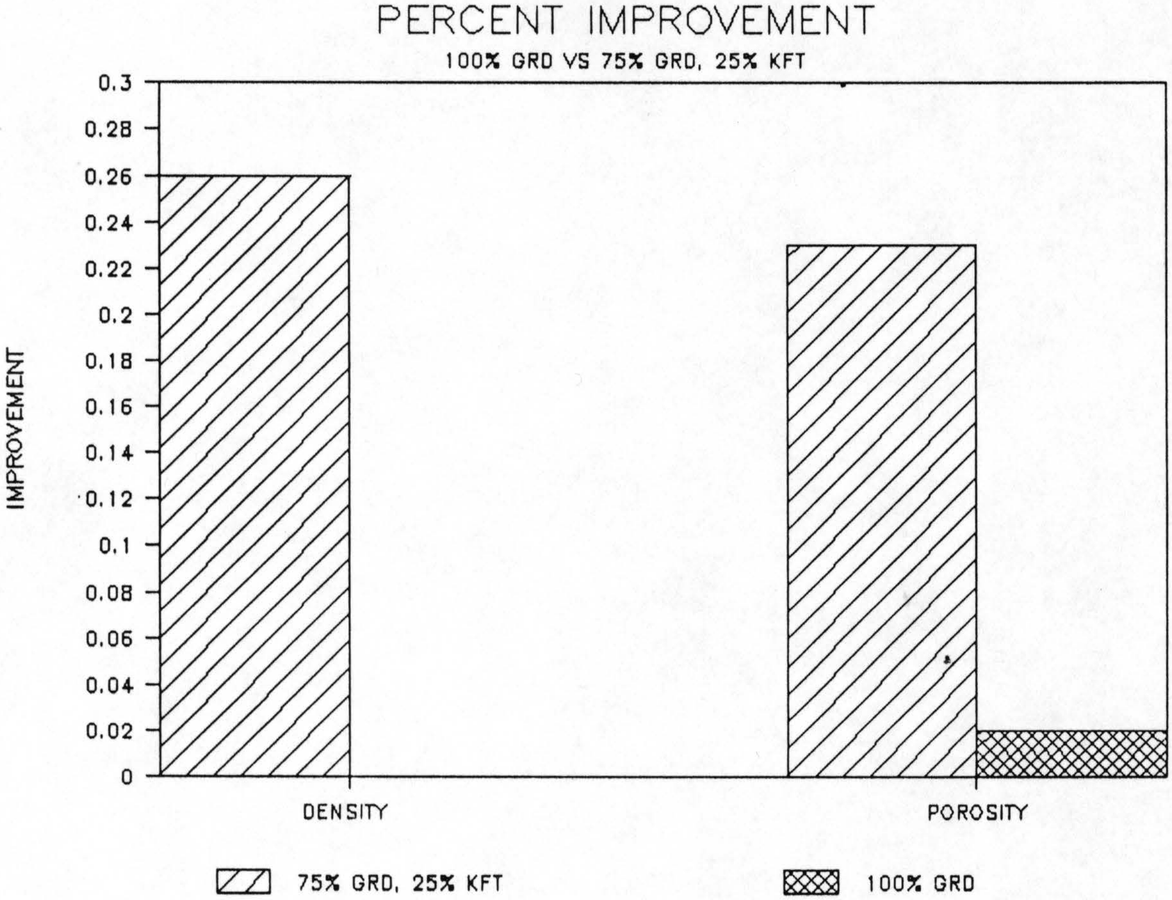


FIGURE 13.



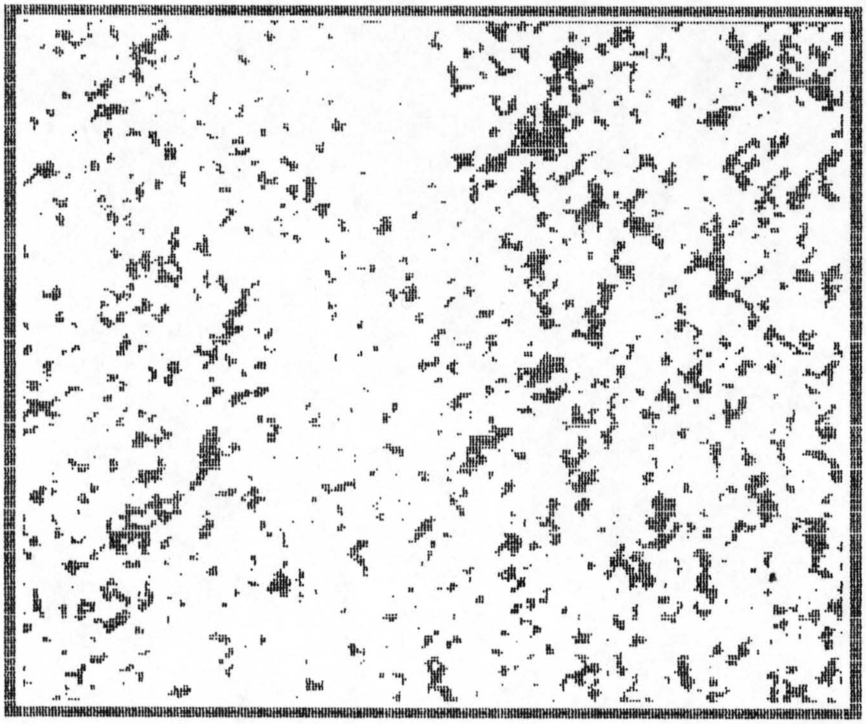
75% Groundwood, 25% Kraft. From this it is easy to see that furnish plays a major role in the formation and reduction of wire mark. The 75% Groundwood, 25% Kraft furnish clearly showed more evidence of reduced wire mark than did the 100% Groundwood.

CONCLUSIONS AND RECOMMENDATIONS

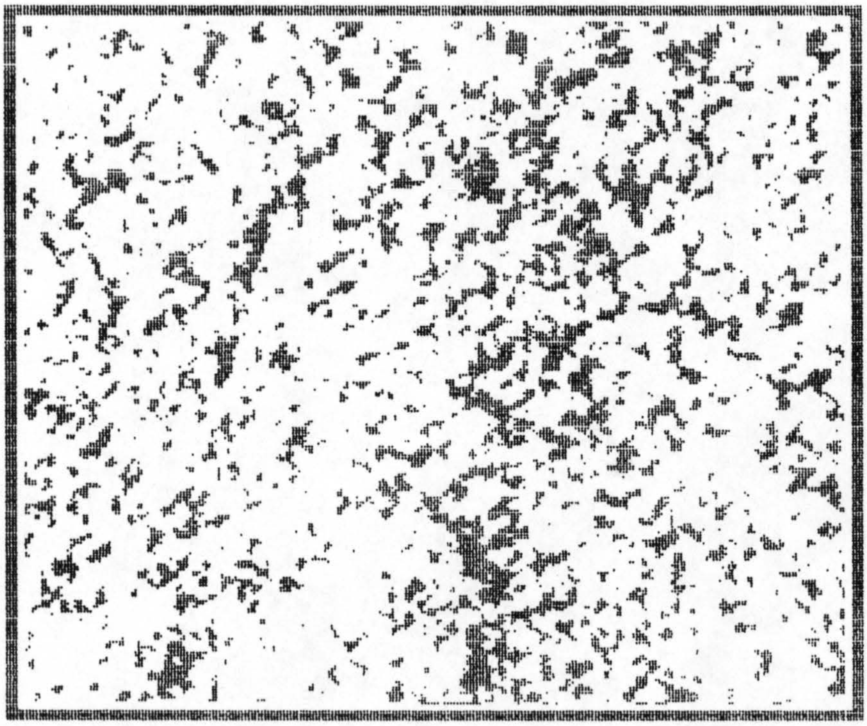
It may not be clearly stated that this thesis proved that sanding the surface of forming wires reduces wire mark, however based on the information recieved from Mead Central Research it does show a potenial

FIGURE 14.

FLOC PICTURES - UNSANDED



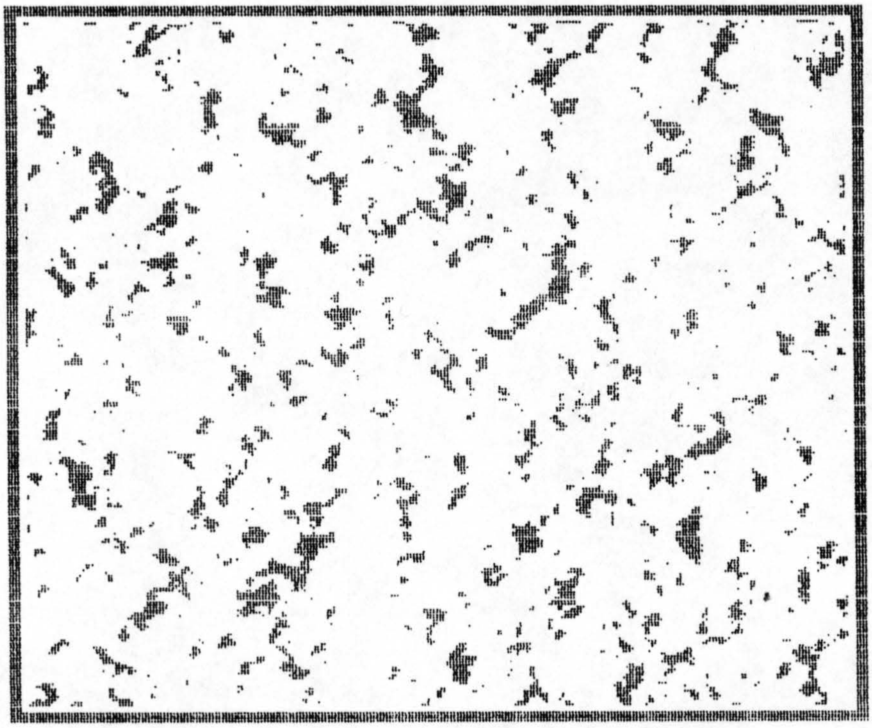
WIRE #3 - Double Layer
% Hole Area - 28.7



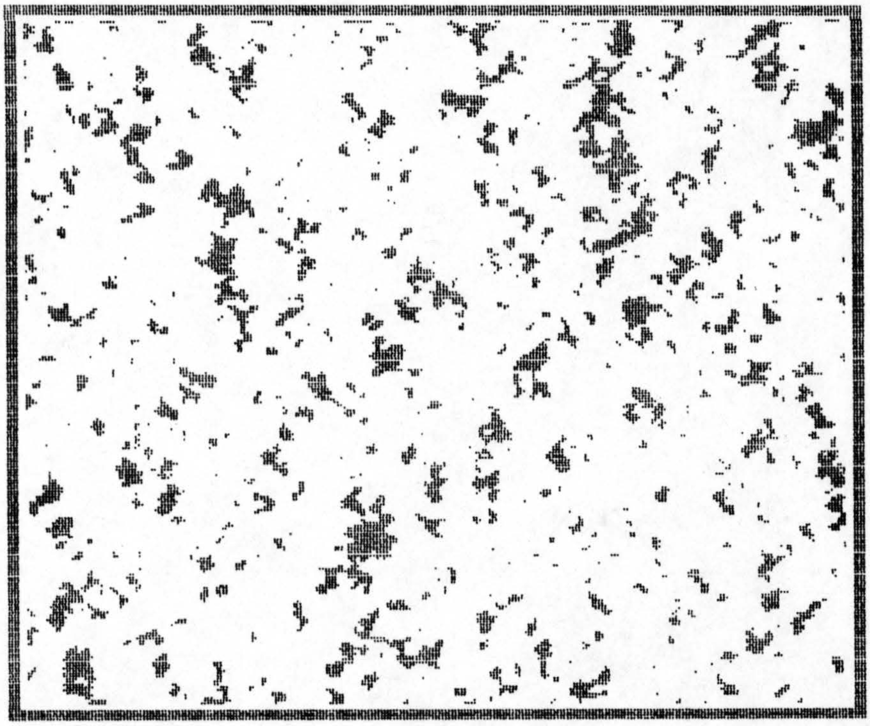
WIRE #4 - Triple Layer
% Hole Area - 34.2

FIGURE 14. (con't)

FLOC PICTURES - SANDED



WIRE #3 - Double Layer
% Hole Area - 17.2



WIRE #4 - Triple Layer
% Hole Area - 19.5

reduction. The sanding of the wire surfaces could have played a large role in the fact that more improvement wasn't seen. If this experiment where repeated an area shich should draw more attension would be the actual wear and life of forming fabrics to determine if it is possible to remove more area from the surface and just how much. This thesis should serve has a basis for more research in a area which looks for improvement.

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APPENDIX IA

CALIPER ON UNSANDED WIRES

WIRE #1 (mils)		WIRE #2 (mils)		WIRE #3 (mils)		WIRE #4 (mils)	
	15.1		16.8		24.5		38.5
	15.1		16.7		24.5		38.5
	15.0		16.8		24.6		38.5
	15.0		16.8		24.4		38.5
	15.1		16.8		24.5		38.4
	15.2		16.8		24.5		38.5
	15.1		16.7		24.5		38.5
	15.1		16.7		24.5		38.5
MAX	15.20		16.80		24.60		38.50
MIN	15.00		16.70		24.40		38.40
AVG	15.09		16.76		24.50		38.49
STD	0.06		0.05		0.05		0.03

APPENDIX IB

CAILPER ON SANDED WIRES-(1)

WIRE #1 (mils)		WIRE #2 (mils)		WIRE #3 (mils)		WIRE #4 (mils)	
	14.0		15.7		23.5		37.4
	14.1		15.7		23.6		37.4
	14.0		15.8		23.6		37.5
	14.0		15.8		23.5		37.5
	14.0		15.8		23.5		37.5
	14.1		15.7		23.5		37.5
	14.1		15.7		23.4		37.3
	14.2		15.7		23.4		37.4

AMOUNT REMOVED	1 mil	1 mil	1 mil	1 mil
MAX	14.20	15.80	23.60	37.50
MIN	14.00	15.70	23.40	37.30
AVG	14.06	15.74	23.50	37.44
STD	0.07	0.05	0.07	0.07

APPENDIX IC

CALIPER ON SANDED WIRES-(2)

WIRE #1 (mils)		WIRE #2 (mils)		WIRE #3 (mils)		WIRE #4 (mils)	
	13.6		15.2		22.6		34.9
	13.6		15.3		22.7		34.9
	13.6		15.3		22.7		34.8
	13.8		15.5		22.7		34.7
	13.8		15.3		22.9		34.9
	13.9		15.2		22.7		34.8
	13.6		15.3		22.6		34.8
	13.6		15.3		22.7		34.9

	WIRE #1	WIRE #2	WIRE #3	WIRE #4
AMOUNT REMOVED	1.5 mil	1.5 mil	2.0 mil	4.0 mil
MAX	13.90	15.50	22.90	34.90
MIN	13.60	15.20	22.60	34.70
AVG	13.69	15.30	22.70	34.84
STD	0.12	0.09	0.09	0.07

APPENDIX IIA

100% GROUND WOOD, OPACITY
UNSANDED WIRES

WIRE #1 (opacity)		WIRE #2 (opacity)		WIRE #3 (opacity)		WIRE #4 (opacity)	
	50.2		47.2		46.5		51.2
	50.4		47.0		46.4		51.2
	50.4		47.2		46.3		51.3
	50.2		47.5		46.4		51.3
	51.2		47.8		46.4		51.5
	51.0		47.5		46.5		51.3
	50.5		47.2		46.4		51.2
	50.2		47.3		46.5		51.4
MAX	51.20		47.80		46.50		51.50
MIN	50.20		47.00		46.30		51.20
AVG	50.51		47.34		46.43		51.30
STD	0.36		0.23		0.07		0.10

APPENDIX IIB

100% GROUND WOOD, OPACITY
SANDED WIRES

	WIRE #1 (opacity)	WIRE #2 (opacity)	WIRE #3 (opacity)	WIRE #4 (opacity)
	50.8	47.9	46.5	51.4
	50.8	47.9	46.4	51.3
	50.9	47.8	46.5	51.3
	50.7	47.8	46.4	51.4
	50.8	47.9	46.4	51.5
	50.7	47.6	46.5	51.3
	50.8	47.8	46.5	51.2
	50.8	47.9	46.5	51.2
MAX	50.90	47.90	46.50	51.50
MIN	50.70	47.60	46.40	51.20
AVG	50.79	47.82	46.46	51.33
STD	0.06	0.10	0.05	0.10

APPENDIX IIC

75% GROUND WOOD, 25% KRAFT, OPACITY
UNSANDED WIRES

WIRE #1 (opacity)	WIRE #2 (opacity)	WIRE #3 (opacity)	WIRE #4 (opacity)
61.2	59.4	58.7	60.3
61.2	59.4	58.8	60.2
61.1	59.4	58.8	60.1
61.2	59.5	58.7	60.3
61.3	59.5	58.9	60.3
61.1	59.4	58.7	60.2
61.1	59.4	58.7	60.3
61.2	59.5	58.7	60.2

	WIRE #1	WIRE #2	WIRE #3	WIRE #4
MAX	61.30	59.50	58.90	60.30
MIN	61.10	59.40	58.70	60.10
AVG	61.18	59.44	58.75	60.24
STD	0.07	0.05	0.07	0.07

APPENDIX IID

75% GROUND WOOD, 25% KRAFT, OPACITY
SANDED WIRES

	WIRE #1 (opacity)	WIRE #2 (opacity)	WIRE #3 (opacity)	WIRE #4 (opacity)
	61.3	59.9	59.0	61.1
	61.2	59.6	59.0	60.8
	61.1	59.8	58.8	60.7
	61.3	59.8	58.9	60.8
	61.3	59.9	58.9	60.6
	61.1	59.7	58.7	60.8
	61.3	59.8	59.0	60.8
	61.2	59.8	58.7	61.0
MAX	61.30	59.90	59.00	61.10
MIN	61.10	59.60	58.70	60.60
AVG	61.23	59.79	58.88	60.83
STD	0.08	0.09	0.12	0.15

APPENDIX IIIA

100% GROUNDWOOD, TENSILE
UNSANDED WIRES

WIRE #1 (lb/in)	WIRE #2 (lb/in)	WIRE #3 (lb/in)	WIRE #4 (lb/in)
0.70	0.80	0.60	0.70
0.78	0.85	0.66	0.80
0.72	0.79	0.67	0.75
0.70	0.78	0.68	0.74
0.70	0.80	0.60	0.75
0.75	0.85	0.65	0.70
0.75	0.84	0.60	0.72
0.72	0.85	0.60	0.70

	WIRE #1	WIRE #2	WIRE #3	WIRE #4
MAX	0.78	0.85	0.68	0.80
MIN	0.70	0.78	0.60	0.70
AVG	0.73	0.82	0.63	0.73
STD	0.03	0.03	0.03	0.03

APPENDIX IIIB

100% GROUNDWOOD, TENSILE
SANDED WIRES

	WIRE #1 (lb/in)	WIRE #2 (lb/in)	WIRE #3 (lb/in)	WIRE #4 (lb/in)
	0.78	0.80	0.68	0.74
	0.78	0.78	0.69	0.70
	0.76	0.79	0.65	0.78
	0.77	0.82	0.68	0.81
	0.77	0.80	0.66	0.75
	0.75	0.81	0.68	0.76
	0.78	0.78	0.65	0.80
	0.77	0.85	0.67	0.73
MAX	0.78	0.85	0.69	0.81
MIN	0.75	0.78	0.65	0.70
AVG	0.77	0.80	0.67	0.76
STD	0.01	0.02	0.01	0.03

APPENDIX IIIC

75% GROUNDWOOD, 25% KRAFT, TENSILE
UNSANDED WIRES

	WIRE #1 (lb/in)	WIRE #2 (lb/in)	WIRE #3 (lb/in)	WIRE #4 (lb/in)
	1.64	1.26	1.24	1.70
	1.60	1.22	1.22	1.70
	1.58	1.29	1.24	1.65
	1.65	1.30	1.27	1.69
	1.68	1.21	1.19	1.72
	1.60	1.25	1.18	1.74
	1.62	1.26	1.25	1.69
	1.64	1.24	1.23	1.70
MAX	1.68	1.30	1.27	1.74
MIN	1.58	1.21	1.18	1.65
AVG	1.63	1.25	1.23	1.70
STD	0.03	0.03	0.03	0.02

APPENDIX IIID

75% GROUNDWOOD, 25% KRAFT, TENSILE
SANDED WIRES

WIRE #1 (lb/in)		WIRE #2 (lb/in)		WIRE #3 (lb/in)		WIRE #4 (lb/in)	
	1.75		1.23		1.35		1.78
	1.72		1.20		1.29		1.79
	1.70		1.29		1.30		1.73
	1.81		1.25		1.35		1.71
	1.80		1.18		1.37		1.78
	1.76		1.20		1.37		1.75
	1.79		1.23		1.35		1.71
	1.72		1.25		1.32		1.89
MAX	1.81		1.29		1.37		1.89
MIN	1.70		1.18		1.29		1.71
AVG	1.76		1.23		1.34		1.77
STD	0.04		0.03		0.03		0.05

APPENDIX IVA

100% GROUNDWOOD, POROSITY
UNSANDED WIRES

WIRE #1 (porosity)		WIRE #2 (porosity)		WIRE #3 (porosity)		WIRE #4 (porosity)	
	260		250		132		170
	275		255		140		175
	265		262		135		182
	260		260		152		170
	270		250		140		175
	280		240		130		180
	260		275		135		185
	265		265		140		172
MAX	280.00		275.00		152.00		185.00
MIN	260.00		240.00		130.00		170.00
AVG	266.88		257.13		138.00		176.13
STD	7.04		10.08		6.38		5.28

APPENDIX IVB

100% GROUNDWOOD, POROSITY
SANDED WIRES

WIRE #1 (porosity)		WIRE #2 (porosity)		WIRE #3 (porosity)		WIRE #4 (porosity)	
	262		255		135		178
	260		252		141		175
	258		250		132		161
	261		246		135		173
	265		243		131		176
	261		256		138		169
	256		254		130		175
	258		250		135		179
MAX	265.00		256.00		141.00		179.00
MIN	256.00		243.00		130.00		161.00
AVG	260.13		250.75		134.63		173.25
STD	2.62		4.21		3.43		5.45

APPENDIX IVC

75% GROUNDWOOD, 25% KRAFT, POROSITY
UNSANDED WIRES

WIRE #1 (porosity)		WIRE #2 (porosity)		WIRE #3 (porosity)		WIRE #4 (porosity)	
	282		270		220		235
	275		275		223		230
	279		271		220		234
	280		268		219		232
	284		269		223		235
	284		276		220		235
	281		273		216		236
	285		275		219		232
MAX	285.00		276.00		223.00		236.00
MIN	275.00		268.00		216.00		230.00
AVG	281.25		272.13		220.00		233.63
STD	3.07		2.85		2.12		1.93

APPENDIX IVD

75% GROUNDWOOD, 25% KRAFT, POROSITY
SANDED WIRES

WIRE #1 (porosity)		WIRE #2 (porosity)		WIRE #3 (porosity)		WIRE #4 (porosity)	
	275		269		175		189
	274		270		170		174
	275		270		174		171
	270		263		179		185
	269		265		179		186
	274		269		175		172
	278		271		178		189
	275		269		175		170
MAX	278.00		271.00		179.00		189.00
MIN	269.00		263.00		170.00		170.00
AVG	273.75		268.25		175.63		179.50
STD	2.73		2.59		2.83		7.92

APPENDIX VA

100% GROUNDWOOD, DENSITOMETER READING
UNSANDED WIRES

eter	WIRE #2 (densitometer reading)	WIRE #3 (densitometer reading)	WIRE #4 (densitometer reading)
0.41	0.39	0.40	0.50
0.40	0.39	0.40	0.50
0.41	0.40	0.40	0.51
0.41	0.40	0.40	0.50
0.41	0.39	0.41	0.52
0.40	0.39	0.40	0.50
0.41	0.39	0.40	0.50
0.41	0.39	0.41	0.50
0.40	0.39	0.40	0.50
0.41	0.40	0.41	0.52
0.41	0.39	0.40	0.50
0.004	0.004	0.004	0.007

APPENDIX VB

100% GROUNDWOOD, DENSITOMETER READING
SANDED WIRES

		WIRE #2 (densitometer reading)		WIRE #3 (densitometer reading)		WIRE #4 (densitometer reading)	
neter	0.40		0.40		0.41		0.46
	0.40		0.39		0.41		0.47
	0.40		0.40		0.40		0.47
	0.40		0.40		0.41		0.47
	0.41		0.40		0.40		0.47
	0.40		0.39		0.40		0.46
	0.40		0.39		0.41		0.46
	0.41		0.40		0.41		0.46
	0.40		0.39		0.40		0.46
	0.41		0.40		0.41		0.47
	0.40		0.40		0.41		0.47
	0.004		0.005		0.005		0.005

APPENDIX VC

75% GROUNDWOOD, 25% KRAFT, DENSITOMETER READING
UNSANDED WIRES

ometer)		WIRE #2 (densitometer reading)		WIRE #3 (densitometer reading)		WIRE #4 (densitometer reading)	
	1.30		1.31		1.28		1.48
	1.30		1.31		1.28		1.48
	1.30		1.30		1.28		1.48
	1.30		1.31		1.29		1.48
	1.31		1.31		1.28		1.49
	1.31		1.31		1.29		1.48
	1.30		1.31		1.28		1.48
	1.30		1.31		1.28		1.48
	1.30		1.30		1.28		1.48
	1.31		1.31		1.29		1.49
	1.30		1.31		1.28		1.48
	0.004		0.003		0.004		0.003

APPENDIX VD

75% GROUNDWOOD, 25% KRAFT, DENSITOMETER READING
SANDED WIRES

ometer)	1.28	WIRE #2 (densitometer reading)	1.25	WIRE #3 (densitometer reading)	1.19	WIRE #4 (densitometer reading)	1.10
	1.28		1.25		1.18		1.10
	1.29		1.24		1.19		1.10
	1.28		1.25		1.19		1.10
	1.28		1.25		1.20		1.11
	1.29		1.25		1.20		1.11
	1.29		1.26		1.19		1.10
	1.29		1.25		1.19		1.10
	1.28		1.24		1.18		1.10
	1.29		1.26		1.20		1.11
	1.29		1.25		1.19		1.10
	0.005		0.005		0.006		0.004

APPENDIX VI
WEIGHT CALCULATIONS

Calculation:

$$\frac{WT}{64} \times 1550 = g/m2$$

$$g/m2 \times .614 = lb/ream$$

100% GROUNDWOOD

	WT #1	WT #2	WT#3	WT #4
	0.756	0.784	0.745	0.732
	0.750	0.780	0.745	0.734
	0.757	0.785	0.746	0.732
	0.756	0.786	0.743	0.731
AVG	0.755	0.784	0.745	0.732

lb/ream #1	lb/ream #2	lb/ream #3	lb/ream #4
11.23	11.66	11.08	10.89

APPENDIX VI - CON'T
75% GROUNDWOOD, 25% KRAFT

	WT #1	WT #2	WT #3	WT #4
	1.21	1.23	1.25	1.21
	1.25	1.29	1.26	1.23
	1.19	1.16	1.18	1.19
	1.22	1.21	1.20	1.21
AVG	1.22	1.22	1.22	1.21

lb/ream #1	lb/ream #2	lb/ream #3	lb/ream #4
18.14	18.14	18.14	17.99

APPENDIX VII
TENSILE INDEX CALCULATIONS

Calculation:

$$\frac{\text{Reading}}{\text{Grammage}} \times 653.8 = \text{Nm/g}$$

* Reading avg.'s from Appendix IIIA-D
* Grammage,
  100% Groundwood = 17.9
  75% Groundwood, 25% kraft = 29.3

100% GROUNDWOOD - UNSANDED

Nm/g #1	Nm/g #2	Nm/g #3	Nm/g #4
26.5	29.8	22.9	26.5

SANDED

Nm/g #1	Nm/g #2	Nm/g #3	Nm/g #4
28.0	29.1	24.3	27.6

APPENDIX VII - CON'T

75% GROUNDWOOD, 25% KRAFT - UNSANDED

Nm/g #1	Nm/g #2	Nm/g #3	Nm/g #4
36.4	27.9	27.4	37.9

SANDED

Nm/g #1	Nm/g #2	Nm/g #3	Nm/g #4
39.3	27.4	29.9	39.5